REMARKS

The applicants thank the Examiner for the review of the application, and for the indication that but for an obviousness type double patenting objection, some of the claims (1-11, 17, 19, and 32-43) which are not otherwise rejected or objected to, would be allowable upon the submission of a terminal disclaimer. A terminal disclaimer is enclosed herewith.

The application contains 43 claims, with claims 44-53 having been withdrawn from consideration. Of these, four (1, 38, 40 and 42) are independent. Two claims (12, 16) have been amended. The specification has been amended at par. 98 to correct a typographical error, which would have been recognized by a skilled person as an error. No new matter has been added. The manner of correcting the error is certain from inspection of the equation that the paragraph discusses.

Turning first to the rejection of claim 12 in par. 2.a) of the Office Action, it has been amended so that antecedent basis is proper, by changing "powder" to —particles—and by deleting "infiltrated" modifying —porosities--.

Claim 16 has been amended to correct an errant dependency.

Turning next to the question in paragraphs 2.c) regarding the meaning of the terms, D2, M2, 440C, etc., as used in claims 18 and 20-29, as discussed in the application at pars. 47-49 and 206, among other places, these names are as established by ASTM International (originally known as the American Society for Testing and Materials) for different useful metal compositions. This standards-making body is mentioned as the originator of the steel specifications in the application. The metal names used in the patent application refer to metals of the same names, governed by a specific ASTM standard. For instance, ASTM standard A 681 cover D2 and H13. ASTM A 600 covers M2. ASTM A 128 covers the austenitic manganese steel. A959 covers 440C stainless steel. Further, the composition of the various named steels, are set forth in the specification in the tables. For instance, the composition of D2 steel, as used in the application and claims, is set forth in Table D, on p. 23 in the header row entitled "D2." The composition of 440C is set forth in Table E3, on p. 62, in the header row entitled "440C." These standards are familiar to a person skilled in the art. The composition of each of the other named items is the subject of an ASTM standard and is also defined in a table in the application (with the same definition as set by the ASTM).

Turning next, then, to the rejection in par. 2. b), of claims 14-16 under 35 U.S.C. § 112, second ¶, owing to an uncertainty as to the definition of the various "modes", and

what constitutes the metes and bounds of the term "near" in the name of one of those modes used in claims 14 and 15, these two questions are addressed generally in the specification at paragraphs 78-115 and are dealt with here together. A general aspect of inventions disclosed herein, is to infiltrate a skeleton made of metal particles of a first composition, with a liquid metal infiltrant of a different composition, to arrive, after infiltration and diffusion of elements, with a fully infiltrated metal body of a target composition.

In par. 73-78, the specification discusses one method to achieve an infiltrated skeleton having the composition of the ASTM standard metal, D2. The specification discusses various "styles" of methods, as the term "style" is used in the specification, for instance in paragraph 78, to arrive at a target composition using corresponding "modes" of complementary composition pairs for a skeleton and an infiltrant. There are four different styles of methods discussed. With each method style, there is a corresponding composition pair mode. The four styles and modes discussed in the specification are: Basic; Near Tie-Line; Off Tie-Line; and Reverse Slope.

Fig. 4 illustrates (among other matters) the relation of the four method styles and four modes of complementary compositions as set forth in par. 110. Fig. 4 is an isothermal phase diagram for the Fe-Cr-C-Mo-V system,

applicable to D2 tool steel. The point T represents a target composition of D2 in the two-phase (liquid + austenite) field with 12% wt Cr, and 1.5% wt C. This target will be used for each of the four mode examples. The relevant temperature is 1306°C (1579 K). Molybdenum (Mo) and Vanadium (V) are both present at 1% wt. Carbon concentrations vary, and are shown on the horizontal axis. Cr concentrations also vary, and are shown on the vertical axis. The balance is Fe.

The Table D on p. 23 sets forth all the compositions and others to be mentioned below.

Basic Mode/Style

Turning first to the Basic mode/style, mentioned in claim 15, the following description is taken largely from the specification, at par. 78. The composition of the infiltrant and skeleton are the same as that of the target, except for the wt% C (with more C in the infiltrant) and compensating wt% Fe (with less Fe in the infiltrant).

If a skeleton having a packing fraction of 60%, with a composition as shown in Table D, the row named KA Skeleton[1] (K is used generally to designate skeleton components) is infiltrated by an infiltrant having a composition as shown in

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[1] (about .3% wt C, and with Cr, Mo and V as in the row marked target of Table D, with the balance Fe)

the row named IA infiltrant[2], then the result at equilibrium at

1306°C (1579 K) would be 60% vol solid and 40% vol liquid,

with equilibrium compositions as set forth in the footnotes

referenced above. This equilibrium temperature is referred to

as T_{PF} because the equilibrium solid amount is equal to the

packing fraction. These skeleton and infiltrant compositions

are complementary in a Basic Mode. Any pair of skeleton and

infiltrant compositions that both lie upon the line KA-IA, and

which also when used in proportions 60/40 would result in the

target composition, as can be determined by application of the

lever rule, would constitute a <u>complementary</u> pair in the <u>Basic</u>

<u>Mode</u>.[3]

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[2] (about 3.5% wt C, and with Cr, Mo and V as in the target
listed above, and the balance Fe)

[3] In general, "complementary" as is used in the application and
the claims, is discussed in the specification at par. 110-115.
Complementary pairs of skeleton and infiltrant compositions KX
and IX respectively include any pair that lie an a line in the
hatched region of a phase diagram, such as Fig. 4, that passes
through the target composition T, and which are set at
compositions such that, given a packing fraction V_{PF} of the
skeleton, a bulk composition made up of a liquid phase and a
solid phase having compositions of IX and KX, respectively, of
appropriate masses, would result in a bulk composition of T,
according to known application of metallurgical analytical
techniques, including the lever rule (rule of mixtures).

Any <u>complementary</u> pair as defined herein will result in
the bulk composition of the target. What will vary, depending
on which mode of complementarity is used, is the degree to
which a final infiltrated body is <u>homogeneous</u> with respect to
non-MPD elements, and, the degree to which the skeleton is
<u>susceptible to erosion</u>. Generally, complementary pairs that
produce a more homogeneous end-product are more susceptible to
skeleton erosion.

Such a composition pair could be used for a skeleton and

an infiltrant. However, this mode can result in <u>erosion</u>,

because the equilibrium liquid is richer in chromium than is

the infiltrant. The required Cr to bring the infiltrant to

equilibrium must come from erosion of the skeleton.

<u>Near-Tie-Line Mode/Style</u>

A second mode of composition pair can be used to avoid

erosion, and is now explained. To eliminate erosion by

adjusting compositions, it is necessary to adjust both the MPD

(e.g. C) and non-MPD (e.g. Cr, Mo, V), concentrations of both

the skeleton and the infiltrant away from their basic mode

concentrations, so that the solid and liquid are nearly at

<u>chemical equilibrium</u> with each other upon infiltration. Doing

this, is called, in the specification, and the claims, the

"near-tie-line" style, using a near-tie-line mode

complementary pair of compositions.

Before discussing the near-tie-line mode, the concept of

tie-line will be briefly discussed. The points S and L are

the respective equilibrium solid and liquid compositions at

this temperature for a bulk composition T (D2), with V_s = 60%

volume solid and V_L = 40% volume liquid. The points S and L

are on a line TL called a "tie-line" (shown as dotted), which

joins the equilibrium solid and equilibrium liquid

compositions. Any composition on the line between the two

points S and L will be composed of a solid having composition

S and a liquid having composition L in amounts that may be found by the lever rule. They have the compositions set in the rows $V_S = 60\%$ and $V_L = 40\%$, respectively.

The liquidus and solidus compositions would be at chemical equilibrium with each other at the infiltration temperature. Thus, no erosion would occur if they were used for the infiltrant and skeleton compositions, respectively. However, having the composition of the skeleton exactly at S on the solidus raises problems.

Any temperature overshoot during heating above the designated infiltration temperature will cause the skeleton to partially melt. Thus, the carbon concentration at that composition is the maximum carbon concentration in the skeleton. Similarly, with an infiltrant composition exactly on the liquidus at L, if the infiltration temperature is slightly below the designated infiltration temperature there could be some solid material in the infiltrant alloy that could clog the gate and retard infiltration. Thus, the carbon concentration at that composition is the minimum carbon concentration in the infiltrant. Therefore, a tie-line mode of complementarity would not be terribly useful as a basis for selecting the compositions of a skeleton and an infiltrant. Too much precision in temperature control would be required to prevent slumping or clogging.

However it is useful to provide a skeletal carbon concentration slightly less than the S concentration, to insure that it does not melt, and to provide higher carbon concentration than L in the infiltrant to ensure that the gate does note clog. Such a combination of infiltrant and skeleton compositions are complementary in a "near-tie-line" mode, as used herein, and as explained in detail below.

The difference in carbon concentration between the skeleton and the equilibrium solid results in the solidus temperature of the skeleton being higher, by some amount, than the temperature T_{PF}. The temperature difference amount is referred to as T_{SAFE}. In general, T_{SAFE} can be any amount, depending on the accuracy of process controls, or even zero. However, typically 50°C< T_{SAFE} and 100°C.

The pair of compositions KB and IB in Fig. 4 are similar in Cr content to the compositions S and L respectively, but differ in C content, to give this greater difference in melting points.[4]

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[4] Thus, the C concentration for KB is 0.3%, which is less than that for S, which is 0.82%. The C concentration for IB is 3.5%, which is more than that for L, which is 2.6%. The Cr concentration in the infiltrant is 15.73% wt, and in the skeleton is 9.76% wt.

The concentrations of other major alloying elements, Mo and V are also adjusted along the tie line between the points S and L, similar to the adjustment of the Cr composition.[5]

This then is a second style method to select the composition of the infiltrant and skeleton, the basic style method being the first. This second style is referred to as a "near-tie-line" style method, because it uses compositions that lie on a line KB-T-IB (from KB to IB), which is near to the tie-line TL. They are not on the tie-line STL, because the carbon amounts are adjusted, to prevent slumping and clogging.

The general properties of a near-tie-line mode pair of compositions are that: they lie on a line that passes through the target composition T; they have non-MPD (in this case, Cr, Mo, V) concentration equal to that of the equilibrium solid and liquid compositions, they have MPD (in this case, C) concentrations equal to that of a basic compositions, and, using the lever rule, they would result in a bulk composition of T, present in a liquid and a solid phase in the packing ratio specified. In the example discussed, it is 60% vol sol.

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[5] Thus the skeleton contains 0.57 wt% Mo and 0.48 wt% V and the infiltrant contains 1.72 wt% Mo and 1.88 wt% V. The concentrations of minor alloying elements (such as Mn, Ni, and Si), and those elements that may be present as known impurities, are not normally varied between the skeleton and infiltrant.

Most of these are general guidelines, only, and can be refined more specifically, as discussed below.

The Office action requests explanation of the "metes and bounds" of "near," as used in the claims to name the "near-tie-line mode." In this sense, "near" is not used to mean a specific proximity to a tie line. Rather it is part of an entire name, having three words, near-*tie*-line, which all together signify the mode just discussed, the "near-tie-line" mode. What is signified is a composition that will be close enough to a tie-line composition, yet far enough away from one, that it will result in a T_{safe} of between 50 and 100°C. The entire mode could be renamed a "blue" mode or "yellow" mode. "Near" has no independent significance of proximity other than as part of the entire name, "near-tie-line" and to distinguish from a tie-line mode.

As shown in Fig. 4, for different values of T_{SAFE} ranging from 0 to a nominal amount, near-tie-line combinations would be any complementary pairs of compositions lieing on a line within the finely hatched regions with hatch lines running from upper left to lower right, between the lines KB-IB and S-L, and bounded by the solidus and the liquidus and the lins KB_{SAFE} and IB_{SAFE}.

A potential draw back of a near-tie-line mode is that it may result in fairly large differences in non-MPD element concentration, e.g. Cr, in the infiltrated body, comparing the

regions that had been skeleton with those that had been infiltrated voids. A third mode is to use a pair of compositions with Cr concentration part way between the two extremes of the basic (IA and KA) and the near-tie-line (IB and KB) concentrations.

Claim 15 specifies an infiltrant having a composition that is complementary to the composition of the skeleton with respect to the target bulk composition, in a mode that is between a near tie-line mode and a basic mode. This then would be any pair of infiltrant and skeleton compositions that are complementary, and that fall within the regions bounded by the lines KA-IA (the basic mode line) and KB-IB (the near-tie-line mode line) as shown in Fig. 4. This region is hatched with the relatively broad hatch marks, running obliquely from upper left to lower right

OFF TIE-LINE

Turning next to the term "off-tie-line" mode, as used in claim 16, an off-tie-line style method, represented by IC and KC in the Fig. 4, uses a composition pair that is complementary in an off-tie-line mode. Any off-tie-line mode combination is actually a mode such as is also specified in claim 15- i.e., in a mode that is between a near tie-line mode and a basic mode. For the representative example signified by the line KC-IC, the Cr concentration in the skeleton and infiltrant is about halfway (the average) between that of the

other two cases. The skeleton material will be less susceptible to erosion than with the basic style method, and there will typically not be as noticeable differences in microstructure between the originally skeletal and solidified infiltrant regions that a typical near tie-line style method would produce.

As mentioned further in the specification, any alloy combinations that lie in between those discussed in connection with a basic style method and a near tie-line style method - for instance along lines in the shaded regions OTL_K and OTL_I shown in Fig. 4, between the line from KB to IB and the line from KA to IA, will provide an off-tie-line style of infiltration. They will present gradually varying erosion and inhomogeneity risks.

The off-tie-line style can be thought of as a mixture of the basic and near-tie-line styles, and can be described mathematically using a parameter R_n, where $0 < R_n < 1$. The skeleton composition $M_{n,K}$ for each non-MPD element, n, can be found using the relationship:

$$M_{n,K} = M_{n,T} + R_n * (M_{n,S} - M_{n,T}) \qquad \text{(Eq. 1)}$$

Thus, in the skeleton, concentration of each non-MPD element in an off tie-line mode can vary continuously and independent of the other non-MPD elements within the range between $M_{n,T}$ (when $R_n = 0$) and $M_{n,S}$ (when $R_n = 1$). When for each

non-MPD element $R_n=0$, then the skeleton composition is identical to the basic method, and the infiltrant composition will also be the same as the basic method infiltrant. When for each non MPD element, $R_n=1$, then the skeleton composition is identical to the near tie-line method, and the infiltrant composition will also be the same as the near tie-line infiltrant.

Turning finally to the fourth mode of complementarity of composition pairs, mentioned in claim 14, a reverse-slope mode is exemplified, for example, by composition pair KD, ID in Fig. 4. In the reverse slope style, the concentration of the non MPD elements in the skeleton is between that of the target value and the equilbrium liquid value at L. Likewise, the concentration of the non-MPD element in the infiltrant is between the target value and the equilbrium solid value at S. The advantages and drawbacks of this reverse slope approach are discussed in the specification at paragraphs 102-109. The morphology, or distribution, of the carbides may be different than any other case.[6]

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[6] Because there is more Cr in the skeleton than in the infiltrant, there is a large driving force to move carbon from the infiltrant to the skeleton. This will have a tendency to dissolve some of the large carbides that form during solidification of the infiltrant and move the carbon into the interior of the skeleton powder. This might provide a tougher material because carbon is removed from the cast grain boundaries and new carbides will uniformly form interior to the austenite grains. However, the homogeneity of the body will be no better than the basic case.

Thus, any complementary alloy combinations that lie in the region between the line that defines those discussed in connection with a reverse slope style method and the line that defines a near-tie-line style method - for instance along lines in the hatched regions shown in Fig. 4, between the line from KD to ID and the line from KB to IB (those regions being hatched with oblique lines running from upper right, to lower left, and the more broadly hatched regions OTL_K and OTL_I with lines running from upper left to lower right, mentioned above as off-tie-line modes) will provide one of the four styles of infiltration discussed: near-tie-line; off-tie-line; basic and reverse-slope. This is claimed in claim 14.

If a complementary pair can be described by an expression such as Eqs. 1 and 2, with $-1<R<1$, then such a pair is complementary in a mode that is between a near tie-line mode (line KB-IB) and a reverse-slope mode (line KD-ID) as claimed in claim 14. If the pair can be defined by such expressions with $0<R<1$, then the mode is complementary in a mode that is between a near-tie-line mode and a basic mode as claimed in claim 15. If the pair can be defined by such expressions with $-1<R<0$, then the mode is complementary in a mode that is between a reverse-slope mode and a basic mode, which range of modes is not claimed apart from the larger range of claim 14.

Turning next to the Office Action's objection to use of the term R_N as being undefined, it is defined in the

specification at pars. 97-109. It is a non-dimensional number between -1 and 1 (including 0) that quantifies, for each of n non MPD elements, where the mode lies, along a spectrum between a near-tie-line mode ($R_n=1$) and a reverse-slope mode ($R_n=-1$), with a basic mode being represented by $R_n=0$.

TERMINAL DISCLAIMER

In response to the Office Action mailed on October 16, 2006, submitted herewith is a Terminal Disclaimer (and requisite fee), disclaiming any portion of any patent to issue based on this application, after the expiration date of the full statutory term defined in 35 U.S.C. § 154 to § 156 and § 173 of issued patent Nos. 6,719,948 and 7,060,222, as set forth in the disclaimer, which is commonly owned herewith. This then overcomes the non-statutory obviousness-type double patenting rejections.

Despite the Applicant's submission of the requested terminal disclaimer, the Applicant does not concede as correct the Office Action's characterization of some of the claims as being "obvious" over the issued claims of either of the two mentioned patents. However, Applicant is willing to accede to the request in the interest of having a patent issue relatively soon.

Attached please find a Fee Transmittal, with authorization to charge $130, two times the small entity

Application No.: 10/723,989
Attorney Docket No.: MIT 10327 US

Terminal Disclaimer fee of $65.00 to Deposit Account No. 19-2553, in the name of the Massachusetts Institute of Technology, for the two Terminal Disclaimers submitted herewith.

Petition for Extension of Time in Which to Respond

Applicants petition for an extension of time under 37 CFR 1.136(a) to respond to the office communication mailed in this matter on October 16, 2006, for a total of one month, up to and including February 16, 2007. If an additional extension of time is required, please consider this a petition therefor. The Commissioner is hereby authorized to charge the fee for one month of $60.00 (for a small entity) to Deposit Order Account No. 19-2553 (Massachusetts Institute of Technology). The Commissioner is also authorized to charge Account No. 19-2553 for any additional extension and/or fee that may be required. A Fee Transmittal is enclosed.

Respectfully submitted,

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February 9, 2007

InternalImac20SJW:Gibralter clients:Clients:MIT:MIT 3DP All:MIT 10327 steel/steel:MIT 10327 US:resp.OA1

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